GROUNDWATER SAPPING CHANNELS: SUMMARY OF EFFECTS OF EXPERIMENTS WITH VARIED STRATIGRAPHY

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Experiments in our recirculating flume sapping box have modelled valley formation by groundwater sapping processes in a number of settings. We have examined the effects of the following parameters on sapping channel morphology: 1) surface slope; 2) stratigraphic variations in permeability cohesion and dip; and 3) structure - joints and dikes.

Figure 1 illustrates the variety of designs used to simulate the gently-dipping strata and joints characteristic of the Colorado Plateau. Run 3 can be viewed as a control because it used uncemented, homogeneous sediment. Runs 8 - 11 were designed to observe the effect of joints in a variety of stratigraphic settings. Joints were constructed by excavating the fine sand in linear troughs and backfilling with coarser, more permeable sand. Runs 27 and 28 investigated the effects of varying cohesion. Cohesion was varied by mixing different amounts of cement (between 0.5 and 5% cement) or loess in the fine sand and by using sediments of varying grain size.

Slope of the sediment surface and the slope of the internal stratigraphy were varied between runs to determine the effect of slope upon the rate of sapping. In particular, we were interested in how slope affects the rate of sapping channel development and sapping channel morphology. Initial experiments using homogeneous sediment (Run 3) indicated that there existed a threshold slope of about 9° below which no sapping channels formed. Below this critical slope, a seepage face formed, but channel incision failed to occur because sediments were not entrained. This slope value is probably diagnostic of the fine sand used in these experiments. Experiments with initial slopes above 11° experienced significant slumping at the expense of channel formation.

The effects of slope in experiments with layered stratigraphy appear to be more complex. Variations in the dip of strata seem to be more important in channel development than surface slope. Runs 14 and 27 contained layered strata with markedly different surface and dip slopes. The 9° surface slope of Run 14 should have resulted in rapid channel formation. However, only small channels formed directly above the toe of the coarse layer. Slumping occurred downslope from this point. The stratigraphy in Run 14 was parallel to the surface slope and no layering was exposed on the seepage face. Most of the groundwater discharge through the coarse layer either flowed along the flume floor to induce slumping or emerged directly above the toe of the coarse layer, taking the shortest route through the fine layer. The surface slope of Run 27 was only 3°, well below the threshold of transport seen in homogeneous fine sand, but experienced significant channel development. Channels developed because the coarse, permeable layer was exposed on the face of a low scarp at the toeslope.

The depth of the sapping canyons also appeared to have been directly related to the thickness of the sediment in the upper strata. In situations where there was a more permeable upper layer (weakly cemented) over a less permeable base (strong cement or loess mixture), the basal layer acted as a base level control on incision. Width of the sapping channels varied considerably with the thickness of the strata and cohesion. Cohesion limited the rate of lateral cutting by retarding the rate of channel wall slumping, resulting in narrower valleys.

Laity and Malin (1985) drew attention to the role of structure in controlling the pattern of channel networks developed by sapping in the Navajo Sandstone of the Colorado Plateau. They noted that on a regional scale tributaries to the Escalante River were asymmetrically distributed on opposite sides of the channel. Structural features such as joints and faults create zones of increased permeability in consolidated rocks which are preferred paths for groundwater flow. Runs 8 - 11 were designed to observe the effect of joints upon the development of sapping channels. In general, main channel trends followed joint patterns and tributaries developed parallel to joints. Our experiments with linear zones of increased permeability suggest that if significant joints are present, sapping valleys will preferentially extend along these avenues of increased groundwater discharge. The degree of influence joints will have upon channel location probably depends upon the relative differences between the permeabilities of the joints and the host rock. As this difference becomes greater, the influence of jointing should become more pronounced.

We are currently experimenting with the development of channels by the combination of groundwater sapping and rainfall runoff processes. Channels formed in Run 28 were established first by sapping and then supplementd by periodic rainfall. The resulting channels exhibited a tapering head area more indicative of runoff valleys and was also characterized by more bifurcation than valleys produced only by sapping. However, close inspection revealed a distinctive scalloped morphology of alcoves developed along the channel walls.

We noticed the importance of groundwater piracy in the evolution of channel networks during most of the sapping experiments. Subsurface piracy was commonplace in all types of stratigraphic settings and regardless of the presence of joints. Between 3 and 6 channels typically formed at regularly-spaced positions across the seepage face during the initial few hours of sapping runs. During the course of a run, one or two of these channels extended headward more rapidly until it captured groundwater from surrounding areas that would have flowed into neighboring channels. Once dominance of a given channel began, the process became self-enhancing and the disparity between development of neighboring channels became even more apparent. Eventually, the pirated channels became inactive and channel evolution was terminated.

Groundwater piracy was best developed during several runs 7 and 18 where conditions were established to mimic the intersection of channels with

subsurface high-level aquifers in experiments designed to simulate channel development on Hawaii (Kochel and Piper 1985). Head regions of the first channels that reach the high-level aquifers widened dramatically and grew at the expense of neighboring channels that were pirated. This process is probably responsible for the light-bulb shaped valleys typical of sapping valleys on the Hawaiian Islands.

These kinds of modelling experiments are particularly good for: 1) testing concepts; 2) developing a suite of distinctive morphologies and morphometries indicative of sapping; 3) helping to relate process to morphology; and 4) providing data necessary to assess the relative importance of runoff, sapping, and mass wasting processes on channel development. The observations from the flume systems can be used to help interpret features observed in terrestrial and Martian settings where sapping processes are through to have played an important role in the development of valley networks.

References

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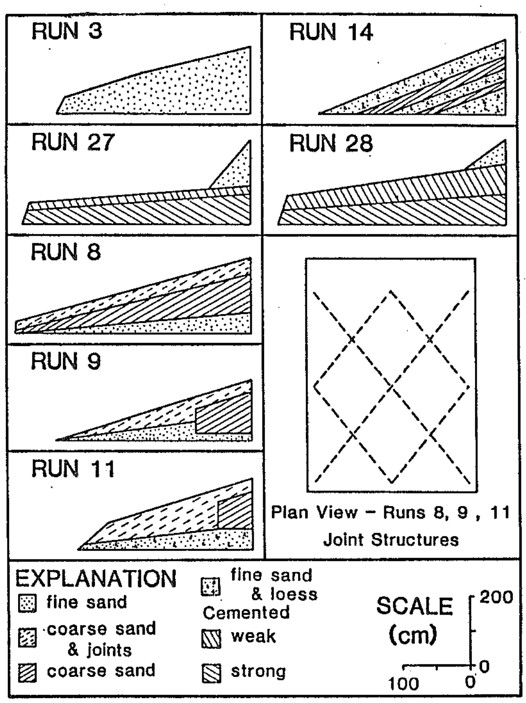

Fig. 1. Schematic of stratigraphic styles used in sapping experiments.